ART. VII. — *Report of the Secretary of the Treasury, communicating, in Answer to a Resolution of the Senate, a Report showing the Amount expended and the Progress made in the Coast Survey.* Senate, 35th Congress, 2d Session. Executive Document, No. 6.

WE have, on two previous occasions, introduced the subject of the Coast Survey of the United States to our readers: first, with a view to make it generally known, and afterward to aid in securing it from a change of plan, or of administration, which, if accomplished, would have lessened, if not destroyed, its usefulness.

On the first of the occasions referred to, we gave the early history of the undertaking, and described the difficulties, dangers, and delays with which it was attended; we explained its merit and utility; and, without enlarging upon the purely scientific and technical parts of geodesy, we aimed to show that the geodetic is the only method by which the survey of an extended region of country can be safely conducted, and thus that it was entitled to the cordial support of the government and the country. The second notice of the Coast Survey to which we here refer was written for the purpose of protecting it against attacks which threatened its character, rather than its existence; and then, also, it was necessary to say something concerning trigonometrical surveying, in order to prove that there are no cheap and rapid expedients by which to produce those results that are the rewards only of profound learning and patient labor.

Eighteen years have elapsed since the last of these papers was written, and now we resume the subject, not to support the Coast Survey, but to record its achievements; not to defend science, but to show how fully science can vindicate itself, when it is allowed full scope for its development.

Previously to 1844, owing to circumstances long since buried in the past, the Coast Survey, though it was in active operation from the year 1832, had not been free from embarrassment, having had to struggle not only with the difficulties naturally attending the setting on foot so great an enterprise, of

which the advantages were not immediately apparent, but also with difficulties pertaining to its internal organization, which affected its atmosphere somewhat like a "continual dropping in a very rainy day." But sixteen years of unremitting successful labor have wholly altered the aspect of its affairs. The grateful task is before us of placing under the observation of our readers some of the results which justify Sir Roderick Impey Murchison in saying, in his address before the Royal Geographical Society, that "the very efficient manner in which the Coast Survey of the United States is conducted by Professor Bache could not fail to make it one of the most *perfect exemplifications of applied science of modern times*," and in speaking of the Annual Reports of the Superintendent as "encyclopædias of great value." This task we shall perform briefly.

The actual progress of this enterprise is in a great measure told only by statistics. The number of sheets in its geographical register, both of topographical and hydrographical drawings; the extent of its triangulations in square miles; the number of its various astronomical, magnetic, tidal, and other observations; its calculations and reductions, its written records in all its manifold departments; its engraved plates, and printed and published maps; — all these, brought into comparison with the amount of money expended, and the number of persons employed, furnish the means of testing its working capacity, and of forming an estimate of the fidelity and industry of its agents. But views based upon statistics merely, and presented in arithmetical and tabular forms, though precise and determinate, are not very attractive to the general reader. We propose, therefore, to take a more popular method of exhibiting the gradual expansion of the Coast Survey to meet the rapidly increasing demands upon its labors; and subsequently to point out some of the most striking instances of the unforced co-operation, resulting from the execution of its strict duties, that has grown up between this institution and other branches of science, as also of art, — which last Mr. Worcester in his great Dictionary has justly defined to be "applied science," and not something "opposed to science," as it is defined by other lexicographers.

The death of the former Superintendent of the Coast Survey, Mr. Hassler, occurred in 1843; and during the same year, by direction of Congress, a plan for the conduct of the Survey, and for its organization, was prepared by a board of officers appointed for the purpose, in which plan the scientific methods employed by Mr. Hassler were fully recognized as the proper basis of the work, while the details of its execution were carefully systematized and improved by the experience of the preceding ten years. The death of the gentleman who alone had controlled the operations of the Survey up to this time, the reorganization, the accession of a new Superintendent, and the rapid extension of our territorial limits, ensuing almost immediately after Professor Bache's appointment, all combined, gave rise to an entirely new state of things, and created an epoch from which are dated the changes that have given to the Coast Survey its present reputation of being one of the most remarkable examples of modern applied science. It was most fortunate for the country that a man of Mr. Hassler's learning, ability, and suitable preparatory education, was present to give a right direction to the views of the government when the Coast Survey was founded; and no notice of the work to which he remained faithful through thirty-five years of varied fortunes ought to omit a passing tribute of respect to his memory and services. It was equally an advantage to the Survey that it found in his successor one not only fully qualified for the post by previous pursuits and by natural endowments, but one who was imbued with that spirit of active, vigorous enterprise which was requisite to meet the demands of Congress and the country.

The earliest step towards a more comprehensive scheme of operations was to divide the whole of the Eastern sea-board, including the Gulf of Mexico, into nine sections, comprising a nearly equal extent of shore-line, with the intention of prosecuting the work separately and simultaneously in as many of these sections as the appropriations would permit.

Previously, the work, proceeding eastward and southward from a single base, measured on the south side of Long Island, had been confined to a few of the Central and Eastern States, and had embraced no other inland waters than Long Island

Sound and its harbors, the waters connected with the city of New York, and Delaware Bay and River. It would seem to have been the original purpose to continue the same lines, measuring occasional verification-bases, and thus to proceed by regular and unbroken connections along the whole extent of the coast. We say this without censure: it was the method adopted in the great European trigonometrical surveys. The ordnance survey of England was begun sixty-nine years ago; the trigonometrical survey of Scotland has already occupied more than fifty years; and it required twenty-two years to complete the survey, even within the narrow limits of Ireland. On the Continent, the application of this *lente ac paulatim* principle is quite as conspicuous. The surveys of France have been in progress nearly a century; those of Russia, more than thirty years; those of Prussia, Austria, and other states, from thirty to seventy years; and they are all still incomplete, and in some cases suspended. These facts must be borne in mind, in order to make a right estimate of the effect of a change of plan, by which the operations of the Survey could be carried on just as many times as fast as the increased number of sections; that is, *nine* times as fast before the acquisition of Texas and California, and *eleven* times as fast subsequently to their accession. Nor does this statement comprise the whole of the new views contained in the first report of the present Superintendent. By the division into sections, not only were the fields of work multiplied, but the different processes of the Survey, so far as not incompatible with one another, were to be carried on simultaneously; and further, the preference was to be given to those processes which circumstances might render the most desirable.

Each section being made the scene of operations which for a time were to be independent, the preliminary step was to measure new bases. As the triangulations extended, these bases became bases of verification for the adjoining sections. Thus the greatest latitude was allowed for the selection of sites for bases, and for the most favorable disposition of the triangles; and at this present time the combination of many sections has united most parts of the Eastern coast of the United States into one comprehensive scheme of triangulation.

The adaptation of this mode of enlarging the work to the Southern coast formed one of its chief recommendations. The inaptitude of that level region for triangles with large sides was apparent without the trouble of a reconnoissance, and it was a question, started early in the history of the Survey, how this obstacle was to be overcome. The most obvious expedient was that employed in the northern section of the great meridional arc of India, where it crosses the flat territory of the Doab. Costly edifices of masonry, with walls five feet thick at the base, and two at the summit, are erected at each of the principal stations, and their height, about fifty feet, is sufficient to command a view above the vegetation. Such expedients were in accordance with the former progress of the Survey, which, advancing in two directions from a central base, was necessarily slow. The value of permanent and conspicuous structures of masonry to designate points of primary triangulation is not underrated; but as a substitute for these, the Coast Survey avails itself of light-houses, churches, and other prominent and durable constructions. Fortifications have been very serviceable, not only for this purpose, but for planes of reference. These objects are not necessarily occupied as stations, but are observed upon, from surrounding positions, so as to be embraced in the network of triangulation, and compose a part of it. In general, temporary means of elevation have been employed, such as the high tripods, with independent stands for the instruments, first used in Delaware Bay by the distinguished surveyor and hydrographer, Mr. Edmund Blunt, the senior assistant of the Survey for the last fifteen years.

The plan of carrying on the operations simultaneously in numerous distinct sections (making so many separate concurrent surveys) involved the necessity for the greatest attainable accuracy, without which the ultimate junction of the sections would have led the assistants to whom were assigned the subordinate triangulations, on coming to the end of their work, to exclaim, "What profit hath he that hath labored for the wind?"

The measurement of the *base line*, which is the starting line or first side of the network of great triangles composing the

fundamental basis of the Survey, is a labor requiring as much as any other a philosophical regard to minute details, and long previous preparation. Upon its correctness depends the value of all that follows. This measurement is obtained from the frequent repetition of small measures: the problem, therefore, is, as far as possible, to remove all errors from the small standards, and to ascertain and allow for those errors which are unavoidable.

The principal source of error is change of temperature. The lines measured by the same bar in winter and in summer might differ very materially in nominal length. The difference in the original base of the Coast Survey, thus measured, might be about twenty feet, and, by a rough estimate, an error of twenty feet in this place would amount in one of the largest triangles to about one tenth of a mile. Next to accuracy, expedition was to be regarded, simply because the number of measurements was so much increased.

Leaving out of the account the two preliminary bases measured by Mr. Hassler in 1817, there have been nine principal base-lines measured since 1832, one of them by Mr. Hassler himself, and three by Mr. Hassler's apparatus, consisting of an assemblage of four iron bars, each two metres in length. The successive contacts of these bars in the process of measurement were optical, and made under a powerful microscope; while thermometers laid along the bar, and touching it, furnished the arguments for corrections for temperature according to experiments previously conducted and tabulated. Excellent results were obtained by this means; but the process was inexpressibly tedious, and the corrections for the expansion and contraction of the iron bars would now be regarded as approximations only. To secure despatch, and to reduce the multitudinous errors arising from variations in the state of the atmosphere in respect to heat, the present Superintendent applied the principle of compensation to an apparatus constructed in the office of the Coast Survey, under his direction.

Measuring bars upon the compensating system were first used by Colonel Colby in Great Britain, and afterward by Mr. Borden in the Trigonometrical Survey of this State. On

the present occasion, however, a principle not before applied was introduced in reference to the dimensions of the bars. It may be thus stated. Bars of brass and iron of the same dimensions will not, owing to their different degrees of conducting power and specific heat, heat equally in equal times; and therefore, while changes of temperature are in actual progress, the system ceases to be compensating, although it finally becomes so when the changes cease, and the temperature is uniform throughout the system. This Mr. Bache corrected by giving to the bars a coating that made them absorb equally, and by proportioning the sections to each other, so that both would have the same temperature during variable temperatures of the atmosphere. To do this satisfactorily, it was necessary to make direct experiments upon the materials of the bars themselves, after having first arranged them approximately by means of the numbers from the books.

The bars (tied in *sets*) are covered with a double conical case of tin to keep the fluctuations of the temperature within moderate limits, and the supports on which they rest are covered with several thicknesses of imperfectly conducting material, for the same purpose.

The length of each apparatus (or *set*) is compared before and after final measurement with a standard iron bar that had been tested in the Coast Survey office by means of Mr. Saxton's reflecting pyrometer. By this instrument, a change of the hundred-thousandth part of an inch in the length of the standard bar is perceptible. Finally, the contact between two sets of bars is made by a blunt knife-edge and a plane of agate, and a lever of contact at the ends of the bars is corrected by a level so delicate that several of its divisions compose a quantity wholly insignificant.

To the preceding description it should be added, that the bars (regulated in size by the relative specific heat of the two metals) were heated above the highest temperature to which they could be exposed in actual use, in order to give them a *set*, — a precaution at first overlooked in the compensation base-apparatus of the British Ordnance Survey, but afterward resorted to from necessity. It will be readily perceived, that this application of the lever of contact and level (first used by

Bessel in the adjustment of standards of measure) has not only increased the delicacy and simplicity of the base apparatus, and diminished the work of manipulation, but also removed several sources of error. By the dependence upon *optical* contact, and the employment of a microscopic apparatus, to determine the distance between the compensation points, two different terms, each having its peculiar standard, are introduced into the measures. Such was the case in the British and Indian Surveys, and Colonel Everest complained of the consequent liability to error, and the burdensome accumulation of petty corrections.

To sum up the foregoing details, we will now inquire, first, into the accuracy of the new base-measuring apparatus, and secondly, into its convenience for handling, and its general adaptability.

The remeasurement of a base of seven and a half miles in India differed 2.4 inches from the first measurement. In a base of seven miles, Dr. Bache found that this difference might be about half an inch, if all the errors were supposed to fall on the same side, which is highly improbable. The probable error in the actual remeasurement of one hundred and twelve yards was less than five thousandths of an inch, and the positive error in remeasuring one third of a mile was nothing.

Secondly, the mechanical arrangements by which the apparatus is placed in position, raised and lowered, moved to the right and left, and produced in line to bring it into effectual contact with its follower and predecessor, are so complete, and such is the convenience of handling for transportation, that a mile has often been measured in a single day without fatigue; and, as an evidence of its adaptability, it is sufficient to say, that it passes over ground varying three degrees in slope, both ways, without the necessity for any addition to its ordinary means of adjustment.

Seeing the Coast Survey thus provided with a plan of operations by which its work can be increased tenfold, or, in other words, by which the time required for its completion can be diminished in the same ratio, — and also with a base-measuring apparatus by means of which this plan can be carried into im-

mediate and safe execution, — we will trace, in the most rapid manner, the progress of the Survey from a period a little subsequent to the date of our last paper, that is, during the incumbency of the present Superintendent. In doing this, however, it is to be remembered that there is one element of work extraneous to the work itself; we mean, of course, money. The appropriations of Congress have been very liberal, though more might have been usefully expended than has been supplied. The purely financial statement will be included in the consideration of the economical management of its affairs.

The operations of the Coast Survey may be classified under the general divisions of field-work and office-work; and these two divisions are subdivided again into geodetics, topography, and hydrography, under the head of field-work; and into computation, drawing, engraving, map-printing, compilation of records and results, clerical labor, and scientific investigations, under the head of office-work. It is unnecessary to say, that each of these subdivisions receives a further partition in the assignment of duties to assistants of different grades, and to the scientific gentlemen, artists, and artisans attached to the Survey.

We have named the out-of-door work in the regular and prescribed order of its execution; — first, the primary triangulation, which, in a hilly country, leaps over the intervening plains with great strides; beneath, perceiving with its delicate levels and plumb-lines the very nature of the geological strata over which it is standing, and above, holding commerce with the skies in the determination of its geographical positions, and of the varying directions of its azimuth; and followed or accompanied by the reticulations of the secondary and primary triangulations, which descend to the lower surfaces, and fill up the large intervals which the master workman leaves behind in his visual journeys through the higher regions. Next comes the topography, which furnishes a descriptive map of all places, and by means of its hachures (*hatchings*), and its accurately defined symbols, contains every minute detail, concerning the nature of the soil, the elevations and depressions, with their contours, the flora and productions, whether uncultivated or

cultivated, and the plots of towns and cities, with their public institutions and open spaces. Resting upon the preceding follows the hydrography, which, sometimes leaving the land at a distance (as in the case of the Nantucket Shoals), depends solely upon conspicuous points of the primary triangulation, and is often compelled to continue that triangulation out of sight of land by using floating objects, such as small vessels and light boats; and again in harbors and rivers derives indispensable aid from the smallest objects, and the faintest features of topographical outline.

But this prescribed order has not been strictly followed. To have adhered to it closely would have trammelled the work, and retarded its usefulness. In July, 1848, instructions were issued for commencing in the tenth section (the coast of Oregon); and in 1850 the eleventh section (the coast of California) was embraced in the Superintendent's scheme of active work. Now, to have proceeded by regular stages in these almost unknown regions would have been utterly to neglect the urgent demands of commerce, and to expose human life to unnecessary risk. Accordingly, the land parties sent to Oregon and California were complete within themselves for all the operations of the Survey; and the water parties were directed to visit in rapid succession those parts of this hitherto little frequented coast which most needed attention, and to furnish with despatch coast-line sketches, independent geographical determinations, soundings, sailing directions, and, where requisite, harbor and river surveys. To meet these and similar wants, on both sides of the continent, as many as forty-three preliminary bases have been measured; and all the information collected in the course of the ordinary, or occasional and extraordinary pursuits of the Survey, is communicated as soon as received, through the newspapers, by preliminary sketches, and by pamphlets, supplied to the chart-sellers, to the Boards of Trade, and Chambers of Commerce, for gratuitous distribution throughout the country. The mention of this flexible accommodation of the Survey to such necessities should never be forgotten, not only because it is a means of increased usefulness precisely suited to our political condition, but because the apparent disproportion in the different parts

of the work on the Western, as compared with the Eastern coast, might otherwise require explanation.

In 1844, there were two centres of work, one including the coast of Long Island and Buzzard's Bay, the other the entrance of Delaware Bay and the upper part of the Chesapeake. In 1845 this work was extended eastward and southward, — a new centre in Albemarle Sound having been added, — eight general and harbor charts were published, and the survey of the Gulf Stream was begun.

To avoid a tedious multiplicity of details, we pass next to the state of the work in 1849 and 1850. In 1849 the operations in the first section had reached the State of Maine; in the second section, from Point Judith to Cape Henlopen, the field-work was nearly completed, and the work of verification and publication was in progress; in the third section, the Chesapeake was completed, and the outside, or coast-line work, was begun; in the fourth section, a base was measured on Bodie's Island, and the Albemarle centre joined to it, and the outer coast on this parallel was begun; the Charleston harbor centre was established in the fifth section, and the Key West harbor centre in the sixth section; the work in Mississippi Sound was continued in the eighth section, and that in Galveston Bay in the ninth section. In 1850, there was added to the preceding the preparation of parties and materials for the work in the seventh section, — the coast of Florida, and keys and reefs in part; and the work in the tenth and eleventh sections, on the Western coast, was satisfactorily inaugurated by a general hydrographic reconnoissance from Columbia River to Monterey harbor.

During the years 1855 and 1856 every section was the scene of active labor. In 1856 the work had reached Mount Desert in Maine, and Matagorda, at the mouth of the Colorado, in Texas; and had covered considerable portions of the coast of California, and of Oregon and Washington Territories, from San Diego to Puget's Sound and Hood's Canal.

A summary of the different steps of progress up to the year 1857, and including that year, shows that the work is certainly more than half done on the Atlantic and Gulf coasts, and the appropriations of every succeeding year secure

a much more considerable rate of advance than the average of the past. A comparison of the relative progress in the earlier stages of the enterprise has proved that it is more economical to conduct it on a large than on a small scale, principally on account of the division of labor, and the facilities for working on different parts of the coast during different seasons of the year. It is obvious, that the sooner the entire results of the Survey can be presented to the growing commerce and navigation of the country, the better. The extent of the coast being determined, economy and utility demand that all the means should be furnished, which, in the hands of its well-trained, active, and intelligent officers, can hasten the time of its completion. A few years more will bring it to a close on the Atlantic and Gulf coasts, if a steady progress at the present rate is secured by the appropriations. We say this, however, without anxiety. Congress has manifested a uniform disposition to sustain the Survey, and to extend its advantages to the remote and border States. What the Survey has actually accomplished, and its reputation at home and abroad, have gained for it unlimited confidence and respect.

Throughout the period we have had under consideration, the publication of the charts has kept pace with the field-work; preliminary charts being published for each year's work, in advance of the elaborate and finished maps. As we have already said, local surveys of dangerous regions have been made, and sketches published in anticipation of the connected work; as, for example, of the Nantucket and Monomoy Shoals, Hatteras Shoals, the Frying-Pan and Cape Fear Shoals, Cape Roman Shoals, Canaveral Shoals, and others. The same course has been pursued in places affording special conveniences for commerce and navigation, and nearly half the harbors and most important inlets of the Atlantic coast have been surveyed, and made known in published charts. Every season, as the hydrographic work comes in, a preliminary chart is drawn and engraved, and the engraved plate receives new additions every year by the electrotype process, — of which more hereafter. Charts of two hundred and thirty-five harbors, inlets, shoals, sounds, bays, and portions of the coast

and of rivers, have been drawn, engraved, and published. The number of maps, charts, and sketches drawn within the year 1857 (our final date), or now in progress, is ninety-five, and the number engraved, or yet in hand, is eighty-four. Of these, twenty-nine are first-class maps, twenty-six are preliminary charts, and twenty-nine are sketches and diagrams. The list of publications of the Coast Survey shows that one hundred and forty-eight sheets of this description may be obtained from the General Disbursing Agent, and the local agents in the principal marts of commerce. The number of copies distributed in one year, under the Act of Congress and regulation of the Treasury Department, has been nineteen thousand seven hundred and ninety-five.

A few facts touching the cost of the Coast Survey, comparing it with itself at different periods, and with other similar works, may be not uninteresting. We have before observed, that, setting aside the desirableness of extending the Survey at once to all parts of the coast, a great saving both in time and money has been effected by the gradual increase of expenditure; and it may be added, that greater accuracy has been at the same time attained. To show the saving in money, we may compare the first twelve years of active operations, from 1832 tc 1844, with the twelve years immediately succeeding. During the first of these periods, the amount appropriated and expended was seven hundred and sixty-six thousand one hundred and thirty-four dollars; and during the second, three million nine hundred and fifty-eight thousand three hundred and thirty-one dollars; that is, the expenditure for the last twelve years amounted to about four times that for the preceding twelve. Now, if we leave out of the calculation the improved observations on the tides, the Gulf Stream explorations, the magnetic and the meteorological observations, (to which there is nothing to correspond in the first of the periods under consideration,) and the additional office-work, arising from the reduction and investigation of all these observations, we shall find that the field-work during the last period was more than seven times as great, and the office-work more than ten times as great, as in the preceding period. Or it may be put thus: from 1832

to 1844, expenditures, 1; field-work, 1; office-work, 1; — from 1844 to 1856 – 57, expenditures, 4; field-work, 7.3; office-work, 10. Supposing the increase for an interval of twelve years to be gradual, both in expenditures and results, the annual increase in the former would be thirty-three per cent, and the annual increase in the latter sixty per cent, showing again an economy of twenty-seven per cent. Thus it appears that the generous desire of Congress to confer the benefits of the Survey upon all parts of the Atlantic and Pacific borders, as soon as possible, has effected a vast gain in time and money. And it is also perfectly apparent, from the above comparison, that the limit of annual expenditures, beyond which it would be neither safe nor economical to go, has by no means been exceeded, and has not even been reached.

For a comparison with former surveys, we may turn to the costly enterprises of Great Britain, France, Austria, and Russia, and may thus not only qualify ourselves to form a just estimate of the method and economy with which our appropriations have been used, but may also see what a largess the liberality of kings and emperors bestows upon geodesy.

The whole amount expended upon the Coast Survey of the United States, up to 1857, was three million seven hundred thousand dollars, including land work and hydrography. At this date the land work and hydrography of Great Britain had cost twenty millions of dollars, and both were incomplete; the land and hydrographic survey of France had cost nearly ten millions of dollars; while during the preceding seventeen years the trigonometric survey of Austria had cost eight millions and a half. The measurement of the great arc from the mouth of the Danube to the northern boundary of Sweden, accomplished under the direction of the illustrious Struve, the completion of which was announced to the Academy of Sciences of St. Petersburg in 1852, occupied thirty-six years; but we have no means of ascertaining its real cost.

The Secretary of the Treasury, in an official letter, dated February 7th, 1849, states the comparative cost of our own and other geodetic work in the following language: —

"I have taken some pains to inform myself in regard to the relative

cost of this and foreign works of a similar kind. Of these, two of the most important works are those of France and Great Britain.

"The tertiary triangulation and topography of France cost on an average one hundred dollars per square mile, or fifteen cents and six mills per acre. This is exclusive of the cost of the great geodetic work by Delambre, Mechain, Biot, Arago, and others.

"The estimates in 1847 for the secondary triangulation and topography of the trigonometrical survey of Great Britain, commenced in 1791 by the Ordnance Corps, are at the rate of one hundred and three dollars and eighty-one cents per square mile, or sixteen cents and two mills per acre. This is exclusive of the army pay of the ordnance officers, but inclusive of the pay of three companies of sappers, numbering three hundred and fifteen, employed upon the work. The near approximation of these sums to each other indicates that they are standards of comparison. They average fifteen cents and nine mills per acre, which is between twice and three times the cost of an acre of secondary triangulation and of topography taken together in the Coast Survey, as shown by the expenditures of 1847 and 1848.

"The surveys of Würtemberg and Hesse-Darmstadt cost respectively twenty-five and twenty cents per acre.

"Similar data for the cost of the hydrography in foreign countries are not before me; but I may mention that the appropriations for hydrography alone, made annually by Great Britain as a contribution to the navigation and commerce of the world, have amounted in ten years — from 1837 to 1847 — to more than four times the appropriation for the survey of the Coast of the United States, land work and hydrography both inclusive; and this is besides the appropriation for the trigonometrical survey."

We have spoken of our Coast Survey with the praise it merits, not without the glow of satisfaction which the contemplation of this noble work is suited to inspire; and, we may add, not without a sentiment of peculiar pleasure in seeing the philosophical spirit of Franklin reproduced in his great-grandson. We have already cited the approving judgment of Sir R. I. Murchison, to which we might add the authority of the equally distinguished President of the Royal Geographical Society, Admiral William Henry Smyth, who said in his annual address of 1850: "The Coast Survey of the United States is a truly national undertaking, and has been most creditably conducted through all its various departments of

science. I have studied the question closely, and do not hesitate to pronounce the conviction, that, though the Americans were last in the field, they have (*per saltum*) leaped into the very front rank." We might, if necessary, furnish similar attestations from Arago, Schumacher, and Humboldt, who have given their unqualified approval to the conduct of the work. At home also the learned societies, — as the American Academy of Arts and Sciences, the American Philosophical Society, the Franklin Institute of Pennsylvania, the Faculties of St. John's College, Maryland, and of the University of Virginia, — as well as the Boards of Trade and of Underwriters, the Chambers of Commerce, and other bodies interested, have been forward in proffering the most flattering testimonials.

But were we to stop here, we should leave our readers very imperfectly acquainted with the nature and whole extent of the valuable services performed by the Coast Survey, some of which are the direct, others the indirect, results of its regular operations. Among the direct results, the most prominent perhaps are the hydrographic discoveries and corrections which have signalized the progress of the work; and it is a noticeable fact, to which we call special attention, that these discoveries have been made, not in places remote and little known, as might have been expected, but in the very central seats and thronged highways of our commerce. A new channel (Gedney's), straighter and deeper than the channels before known, over the outer bars of New York harbor, is the boon conferred upon our commercial emporium. In the beaten path of navigation to Europe from the Middle States, and upon the border of our own coast, a hidden, unsuspected danger has been discovered and marked out, "a very dangerous flat, and fatal, where the carcasses of many a tall ship lie buried," Davis's New South Shoal. Massachusetts Bay, Buzzard's Bay, Long Island Sound, Delaware Bay, Chesapeake Bay, and, not to continue a dry list of names, almost all the harbors, rivers, and inlets upon the Atlantic coast, have been improved in their navigation, and that chiefly by the actual discovery of useful channels or of previously unknown perils. The list of the discoveries of this kind amounts to between one hundred and forty and one hundred and fifty. These benefits,

however, constitute the proper and expected fruits of the work; but it is not a little remarkable, that they should most abound in the places supposed to be best known, such as Ammen's Rock on Cashe's Ledge, Stellwagen's Bank in Massachusetts Bay, Blake's Channel in Delaware Bay, and Maffitt's Channel in the harbor of Charleston, South Carolina.

The exploration of the Gulf Stream comes under this head. It affords the earliest indication of approach to our coast, along which it runs at such a convenient distance as to mark the line of transition from the waters of the ocean to those of the coast, and to warn the seaman to have his sounding apparatus in readiness, and prepare his anchors. And to so good an account has this invaluable warning been turned, taken in connection with the peculiarities in the form of the bottom on different parts of the coast, that we are justified in saying that, of the frightful wrecks which have frequently occurred on the coasts of Long Island and New Jersey, few would have happened if the sailing directions of the Coast Survey for the port of New York and its approaches had been earlier in hand and strictly followed. These directions have been printed in a separate pamphlet for gratuitous distribution by the Life-Saving Benevolent Association of New York.

The objects in view in the exploration of the Gulf Stream are not solely nautical, and for immediate utility; they are also scientific, and of general interest. The observations of Lieutenant George M. Bache — "whose life fell a sacrifice to his zeal in the discharge of his duty, and whose loss science was called upon to mourn, just as he was commencing, with his accustomed ardor, the investigation of one of the most interesting phenomena of our globe" — have been published elsewhere, and are regarded as of the highest value.

The Coast Survey has met all other claims upon its service; such as questions as to harbor improvement, and lights, buoys, and beacons throughout the Atlantic, Gulf, and Pacific coasts; local surveys; data for every project for the advancement of commerce and navigation; and questions of naval and military defence. Upon this last subject, the eminent soldier at the head of the Engineer Corps employs the following language: —

"For many years the Engineer Department has had no other re-

source than the Coast Survey, for the general information necessary for the determination of the sites of new fortifications. It has often been without other resources as to local topography and hydrography. It has been enabled, by this aid, greatly to expedite the construction of defensive works of the highest necessity; and I must not omit to add, that the operations of the Coast Survey have, on some occasions, by the kind consideration of the Superintendent, been specially arranged in the order of time, and in the manner calculated soonest to supply our necessities. . . . .

"In relation to the improvement and preservation of harbors, it may be said, generally, that, great as the function of exhibiting the coast in its present state may be, a not the less important one is the detection of its disturbances; for only on the exact knowledge of these, (already found by the labors of the Survey to be great, various, and often threatening,) can any judicious precautions and remedies be founded."

A commission, of which Professor Bache is a member, has recently been appointed by the general government for the scientific examination of Boston harbor, and it will be indebted almost exclusively to the Coast Survey for the information on which its conclusions and recommendations will rest. Commissions, or councils, connected in a similar manner with this work, have been appointed for most of the important harbors and rivers, from Portland, Maine, to the St. John's and Apalachicola, inclusive.

We speak of the foregoing as the expected results, as the returns due to the public; and we may observe, that the usefulness of the exact measurements of the Coast Survey in relation to the frequent changes of our alluvial sea borders was pointedly referred to, and anticipated by us, in the last of the papers mentioned in the beginning of this article.*

Perhaps we ought also to place in the same class of expected results the contributions of the Coast Survey to those branches of applied science which are intimately connected with, or included in, the science of geodesy. We have already noticed the new base apparatus, with which the first step is taken. In the second step — the measurement of the angles of the primary triangulation — a change in the mode of observing

* No. CXV. pp. 452, 453.

has been introduced and steadily practised, which consists in keeping up the observations in all states of the atmosphere, when the signals are visible, instead of confining them, as before, to days when the signals present a well-defined and steady image. The aim is, to ascertain by trial (involving a discussion of the observations in connection with the changes in the appearance of the signals) the number of observations of this last kind, so as to reduce the probable error to what may be deemed the unavoidable errors of instrument and observer. By applying this mathematical test of the least probable error to observations made under such conditions as are not unfavorable and of frequent occurrence, the rapidity of the work has been increased, and its value enhanced rather than diminished.

Owing to the irregularly elliptical form of the earth, it is necessary to multiply independent determinations of the latitude of the points of main triangulation. For this purpose, the method of measuring astronomically differences of latitude by the zenith telescope, invented by Captain Talcott, late of the Engineers, has been employed for the first time for geodetical purposes. A description of this method, with examples from the Coast Survey, has been published in a handsome form (by order of the Topographical Bureau of the War Department), by Captain T. J. Lee, whose valuable labors while attached to the Survey were chiefly devoted to astronomical and magnetic observations. It appears from this publication, that the latitude is given by a single night of observation to a fraction of a second; and that in four or five nights it can be determined with the minutest accuracy of which astronomical measurement is susceptible. At the twelfth meeting of the Association for the Advancement of Science, Professor Bache made the remarkable statement, that, in the observation of the same stars, the same observers with different instruments, and different observers with the same instruments, brought out the same results. A comparison of latitudes deduced geodetically from a central point with the nice determinations of the zenith telescope, has led to the discovery of certain changes in the level, which could be attributed only to variations in the form and density of the materials composing the earth's crust.

These variations are *similar* to those caused by the proximity of mountains, but had hitherto escaped notice. A similar discovery was afterward made by Major-General Colby, and appears to have been anticipated by La Place in the opinion given by him in the Chamber of Peers, in 1817, upon the topographical map of France: "If the latitudes of the extreme points (of certain lines) are observed, and the length of the seconds pendulum corresponding to these points measured, a great deal of light will be thrown upon the figure of the earth, and upon the irregularity of its degrees, and of gravity." To what extent this astronomical *divining-rod* may be used by geologists in deducing from differences of density or the want of homogeneousness of structure the nature of the underlying strata, is an inquiry which at present admits of only a speculative answer.

As in the latitude, so in the longitude, the Coast Survey has enriched what it touched; with this difference, however, that in the former it improved methods already known, while in the latter it has invented a new method, which now takes precedence of all others, where it can be employed. To have ascertained the availableness of the electro-magnetic telegraph for the exact determination of differences of meridian, to have prescribed from experience the details of the process now known in Europe as the *American Method*, and to have invented the register for recording the observations, constitute a merit and a distinction which history will assign to the Coast Survey. The observations and the mathematical investigations belonging to this important undertaking were made, under the direction of the Superintendent, by the late distinguished astronomer, Mr. Sears C. Walker. It has been shown that, under favorable circumstances, and with due care in the use of the transit instrument, the astronomical difference of longitude between any two stations of a trigonometrical survey may be determined by telegraphic signals, with a degree of precision of the same order as that with which the difference of latitude is determined,—the inaccuracy depending upon the same causes that govern the deviation of the plumb-line. The French are engaged in the redetermination of the longitudes of their great trigonometrical survey by this American method of the electric telegraph.

We purposely avoid detailed descriptions of instruments and methods, in both cases, because we are dealing only with general results; but since the accurate determination of latitude and longitude lies at the foundation of all geography, and since most of the States through which the Coast Survey passes will undoubtedly avail themselves of the bases it is able to supply, to form correct maps of their own territories, under circumstances very favorable to economy and accuracy, it seems hardly possible to overestimate the value of these additions to the common stock of astronomical knowledge.

Leaving now the route we have thus far followed, we will turn aside from the regular work of the Survey, to consider for a moment its indirect and collateral relations with general science, and with applied science, or art. We shall find here some new and surprising proofs of the mutual connection of the physical sciences. We will present a curious instance of this connection, which recently occurred in the Coast Survey, and, after being communicated to the American Association for the Advancement of Science, was published by the Superintendent in the *American Journal of Science and Arts.* In February, 1855, Professor W. P. Trowbridge (known by his contributions to the meteorology of the Western coast), observed that singular curves had been traced by the self-registering tide-gauge at San Diego, on the 23d and 25th of December; and having satisfied himself by an inspection of the meteorological records, and from the length of the curves, that the irregularities could not be produced by disturbances from storms, he decided that "there was every reason to presume that the effect was caused by a submarine earthquake." When the record sheet of the self-registering tide-guage at San Francisco was examined, similar irregularities in the curves for the same days were found upon it. About the 20th of June, accounts were received from Japan of a violent earthquake that occurred on the 23d of December, in which the Russian frigate Diana was much injured. There were several shocks; the sea rose five or six times in a wave thirty feet above its ordinary height, overflowing the town of Simoda in the island of Niphon, and carrying houses and temples before it in its retreat. Yeddo was injured; the fine

city of Osaka was entirely destroyed; and the whole coast of Japan suffered more or less damage. Having taken every precaution to obtain the most exact dates and incidents within reach, Professor Bache determined, first, from a comparison of the times, the rate of motion of the earthquake wave to be from 6 to 6.2 miles per minute, or between three hundred and sixty three and three hundred and seventy miles per hour; secondly, by combining this rate of motion with the periods of oscillation, he determined the length of the wave on the San Francisco path to be between two hundred and ten and two hundred and seventeen miles; and thirdly, by applying a rule laid down by Airy in his *Tides and Waves*, he determined the mean average depth of the sea on the San Francisco path to be two thousand three hundred and sixty-five fathoms, or 2.68 miles, and the corresponding depth on the San Diego path two thousand one hundred fathoms, or 2.38 miles. Mr. Mallett, in the appendix to the fourth and last of his learned and able reports *On the Facts and Theory of Earthquake Phenomena*, to the British Association, copies largely from Dr. Bache's paper, and says: "It is, up to the present time, almost the only record, of scientific pretensions, of the phenomena of earthquake great sea-waves, and is a model for those engaged in tidal observations upon British or European coasts, of what is needed to make their results connect usefully with the requirements of those occupied in seismical inquiry." These investigations have converted the self-registering tide-gauge into a new and valuable seismometer. The connection between the Coast Survey of the United States and the researches of Mr. Mallett of Delville and M. Perrey of Dijon into the theory and facts of earthquake phenomena, is so little apparent at the first glance, that it might seem incredible. The approximate determination of the average depth of a portion of the great North Pacific Ocean, seconding and co-operating with the long-continued efforts of the most eminent hydrographers to solve the same and similar problems, is another instance of the intimate and helpful relations established between the labors of persons employed in distinct fields of physical science.

The connection of which we speak is presented in a still more interesting and important light, when we view the depths

of the great oceans in their cosmical relation to the astronomical problem of the tides. In the tides, the oscillation of the second kind, as it is called, upon which depends the difference of two consecutive tides in one day, is much less than it should be, according to the theory of Newton; and La Place has shown that, if the depth of the sea were the same throughout, the difference between two consecutive tides would be reduced to that caused by local circumstances. From the want of harmony between theory and observation it is inferred that the variations from a mean depth in the sea are not great. "The mean depth of the Pacific Ocean is supposed to be about four or five miles, that of the Atlantic only three or four, which, however, is mere conjecture." "The density of the sea being but one fiftieth, nearly, of the mean density of the earth, that fluid must have little influence upon the variations of the degrees, and of gravity, and upon the two lunar inequalities of which I have just spoken. Its influence is still further diminished by the *smallness of its mean depth.*" After proving that the surface of the terrestrial spheroid would be nearly in equilibrium if it became fluid, La Place adds: —

"From this, and from the fact that the sea leaves bare vast continents, we conclude that it cannot be very deep, and that its mean depth is of the same order as the mean height of the continents and islands above its level, a height which does not exceed a thousand metres (0.62 mile). This depth, then, is but a small fraction of the excess of the radius of the equator over that of the pole, an excess which exceeds twenty thousand metres. But in the same manner as lofty mountains cover some parts of the continents, so there may be great cavities in the basin of the sea. Yet it is natural to suppose that their depth is less than the elevation of high mountains; because the deposits of rivers, and the exuviæ of marine animals, carried along by the currents, must in time fill these cavities."

La Place proceeds to speak of the importance of this result to natural history and geology, and remarks: —

"The sinking of one part of the basin of the sea exposes another part of it, of an extent so much the greater as the sea is the less deep. Thus vast continents may have emerged from the ocean, without great changes in the *figure of the terrestrial spheroid.*"

This question of the probable mean depth of the sea, which we have seen to be so important in its bearings, is partially and to that extent satisfactorily answered; and the Coast Survey, in the performance of one of its most simple practical duties, has lent confirmation to the results of the great Frenchman's inquiry into "the invariability of the axis of rotation of the earth at the surface of the terrestrial spheroid, and the uniformity of this rotation, upon which all astronomy reposes."

The floor of the great seas supplies us with another occasion for exhibiting the mutual dependence of physical studies, and their applications to the wants of daily life. By the inspection of a nautical chart, it will be perceived that the two principal objects of the soundings marked upon it are to give the depth of water, and the distinctive character of the bottom,—whether hard or soft, sand or mud or shells, or a mixture of two, together with the color of the materials. For a long time, no further use was made of these materials brought up by the lead from the long shelving banks of quartzose sand that front upon our Atlantic border. But having been placed under the microscope, they disclosed matters of interest to the geologist and naturalist.

The microscopic examination of the specimens of soundings was begun by the late Professor J. W. Bailey of West Point, the result of whose labors was published in the Smithsonian Contributions to Knowledge, in the Coast Survey Reports, and in Silliman's Journal. Several new species of *Foraminiferæ*—a family which constitutes the greater part of the submarine fauna in the profounder depths—and of *Diatomaceæ* were described by him, and their relative abundance at different depths pointed out. One of the most interesting results of his researches was the discovery of the fossilization of the *Foraminiferæ* in certain localities, and of the fact that the substance called green sand by geologists, which has given its name to an important formation in the cretaceous series, is composed of these fossilized mollusks, and that the process is going on now at the bottom of the ocean, in some places near our coast.

A large number of specimens were also examined by Mr. Pourtales. He first pointed out the fact that the number

of specimens of *Foraminiferæ* found in the soundings increased very much with the depth, so that on our Atlantic and Gulf coast, at least, after reaching a depth beyond one hundred fathoms, the sounding-lead brings up *Foraminiferæ* almost entirely without admixture of other materials. The soundings taken on the line of the Atlantic telegraph have since confirmed this fact, and extended the range in depth of these minute organisms to nearly two thousand five hundred fathoms. By designating with colors on a map the positions in which the various species of *Foraminiferæ* were found more or less abundantly, their distribution according to depth is rendered very evident. Thus the hundred-fathoms line appears to form nearly the limit towards the shore for the *Globigerinæ*, which form the greater bulk of those abundant deposits mentioned above. Other characteristic species are seen to inhabit the shallower parts, some being confined to the region between ten and fifty fathoms, while some, beginning at twenty-five fathoms, extend to sixty or seventy. The region in which the formation of green-sand is going on appears to be a band, nearly on the hundred-fathoms line, off the coast of Georgia, Florida, and South Carolina. The *Foraminiferæ* are rather rare near the shore on our Atlantic coast, but are extremely abundant in the calcareous sands of the Florida Keys. In a zoölogical point of view, these investigations have been of much interest. About one hundred and sixty different species of *Foraminiferæ* have been found on our coasts, a great many of which are probably new to science.

We have already spoken of the exploration of the Gulf Stream; and we might enlarge upon the importance of an investigation which has led to the knowledge of the "distribution of temperature at different depths," of the "distribution of temperature at the same depth on different sections," of the "connection of the figure of the bottom of the sea with the distribution of temperature," and "of the lateral limits of the Stream."

The researches of the Coast Survey into the tides and cotidal lines of both our Eastern and Western coasts demand separate treatment, on account of their value to navigation, and their theoretical deductions.

The geological examination of Florida Reef, by Agassiz, made under the auspices of the Survey, has resulted, we have the highest authority for saying, in one "of the most important contributions by which American geology has ever been enriched," that is, the discovery that the peninsula of Florida is of recent origin; that it has been formed by the growth of successive coral reefs, from north to south; and that this growth is still slowly proceeding.

Our knowledge of terrestrial magnetism, — its periodical changes depending upon the hour of the day, the season of the year, and the regular interval of years, — and of magnetic storms, with their diurnal, annual, and decennial periods, as established by Major-General Sabine, has not failed to receive its share of elucidation from the labors of the Coast Survey.

But we dismiss these topics, that we may adduce one or two examples of the practical application, by the Coast Survey, of the most valuable results of experimental science. Here we would first speak of the electrotype, which has been developed into a high state of efficiency, and has conduced to the economy of time, labor, and money. It is used principally to perpetuate the publication of the charts and maps of the Coast Survey. All electro-metallurgical methods are founded upon the observed fact, that if a body is immersed in the solution of a metal, and kept negatively excited, it receives a gradual accretion of the metal in solution. This principle admits of two forms of application, or leads to two distinct methods or processes of electrotyping; — one called the *single-cell process*, in which the object that receives the deposit is made part of the electrical generator; the other, called the *battery process*, in which the electrical generator is distinct from the objects receiving the deposit and the vessels containing them. The latter is the method used in the Coast Survey.

We omit all description of the electrical generator, or battery, its preparation for use, and the mode of attaching the galvanometer, because they embrace details uninteresting, probably, to the general reader. Assuming the battery to be in order, when an engraved plate is to be electrotyped, the two chief desiderata are to put the silver plates in the most complete negative condition, and to keep all the plates in perfect

metallic connection with the main conductors. For the first of these purposes, it was the European practice to film over the silver plate with a spongy deposit of platinum; but the efficacy of this method is of short duration. It has been discovered in the Coast Survey office, that by occasionally immersing the silver plates in the perchloride of iron — which has the property of dissolving all the metal positive with regard to silver, and leaving the silver untouched — they are maintained in their primitive energy of action. Another peculiarity of the Coast Survey method is the manner of suspending the zinc and silver plates. The latter are suspended by lead, to avoid the disturbance of the electrical relation of the plates consequent upon the use of a metal soluble in sulphuric acid, or of a metal subject — as iron is — to rapid dissolution from the electrical effect of the silver. But the zinc plates are suspended by iron, because, unlike the lead (which is liable to disintegration by mercury), iron refuses to unite with the mercury covering the zinc, is rendered negative by the zinc, and is thus protected from destruction. A third peculiarity of the Coast Survey method consists in the manner in which the deposited copper is prevented from cohering with the engraved plate, and forming an inseparable mass. After the plate has been cleansed by alkalies, acids, and mechanical appliances, till it is *chemically clean*, it is washed in a solution of cyanide of silver, from which it takes a pearly hue, then in water, and then in alcohol. While it is still wet with alcohol, a solution of iodine in diluted alcohol is poured over it, and about a minute afterward the iodine solution is washed off with alcohol. Enough of iodine is still left, however, to give the plate when dry a slightly iridescent appearance. This method of iodizing the matrix, to prevent cohesion, has removed all risk of injury to the engraving, though before its discovery some disastrous consequences resulted from the early trials. The application of heat to vaporize the iodine, the regulation of the current of electricity so as to prevent the granular deposit of the copper, and the length of time for which the engraved plate is allowed to remain in the vat, have been all decided by actual experiment.

The first electrotype copy produced is an *alto*, which, being

subjected to the same processes as the engraved plate, furnishes a perfect fac-simile of the latter; and the copy only is used for printing the charts, the original engraved copper-plate being kept in the fire-proof building belonging to the Coast Survey.

The cost of the electrotype copy is about three times that of the blank copper on which the original engraving is made. It will afford a just idea of the value of these improvements and discoveries in the electro-metallurgic processes, to mention, that it took forty days at the beginning to finish a plate which can now be made in two days. In several instances the electrotypes have been in the hands of the printer in less than twenty-four hours after the requisition for them was signed.

The same views of economy and expedition have led to some special experiments in photography, the aim of which is to employ this art in furnishing the reduced drawings that are placed in the hands of the engraver. The suggestion was a natural one. It was met at the outset with this difficulty, — that the faithful natural copyist, without the power of selection, portrayed the distortions which the field-sheets of the Survey rarely fail to suffer from exposure to the atmosphere; it was requisite, therefore, to discover some method of making selections, and correcting errors.

The recent improvements in photography have been chiefly in the optical arrangements. To have a clear conception of these, it must be understood that there are two kinds of cameras employed in photography. One of them is constructed solely with reference to rapidity in producing the picture; and this is the sort used in taking likenesses, and pictures of moving objects, which are obtained in a fraction of a second. The other form is favorable to correct delineation, but proves to be very slow in its operation. Early in the introduction of the photographic art, the celebrated mathematician, Professor Petzval of Austria, applied himself to the calculation of such forms for the optical part of the portrait camera as would produce the most rapid action, and clearness of delineation combined. The making of these "portrait combinations" was intrusted to the optician, M. Voigtlander, and the cameras have received his name. The Voigtlander lenses are admi-

rable instruments for photographic portraiture; but the image they make is not a strictly true copy, only the central parts being minutely delineated. The want of sharpness in the image, except in the centre of the field, arises from the object's having a spherical form, while the picture is necessarily flat; and it is only when the plane is normal to the surface of the sphere that the best effect is produced. This defect has been remedied by Professor Petzval's orthoscopic (*line-viewing*) lens, between which and the portrait lens the difference is, that in the latter the aim is to concentrate the greatest amount of light upon the image, while in the former the end in view is the refraction of the incident rays at the same relative angles at which they fall upon the lens. By this means, in the orthoscopic pictures, several objects preserve their relative sizes and lateral distances. Hence the fitness of this method for producing reduced copies of drawings. The orthoscopic lens in use in the Coast Survey will make a picture fifteen inches in diameter, free from sensible error.

It is employed to furnish a reduced chart in the following manner. The primary charts, being supposed to be distorted by shrinking, must first be corrected. For this purpose, a sheet of transparent cloth called *tracing vellum* has the latitude and longitude lines of the chart correctly laid down on it, which divide the vellum and the chart into corresponding squares. The vellum is then laid on the chart, and such parts of the latter as are required in the reduced copy are traced over, square by square, the vellum being shifted so as to distribute the errors of each square, and thus to make the whole error inappreciable. In tracing the work the exact contour cannot be followed: many details must be omitted, especially those which lose their significance in the reduced size. The tracing on the vellum is presented to the camera reversed, in order that the collodion positive may not be reversed, as it appears in ordinary daguerreotypes and ambrotypes.

The ambrotype thus obtained from the tracing furnishes the elementary lines for the engraved chart. The ambrotype or collodion positive having been obtained, the tracing is presented obversely, or with its face outward, and another ambrotype is obtained as before; but this picture is reversed. It is

carried through the chemical process, which leaves the parts that were white in the tracing, black, and the parts corresponding to the black lines, transparent glass.

From this negative a print on paper is made, by preparing the paper with nitrate of silver, covering it with the negative, and exposing it to the sun. The light, passing through the transparent lines of the negative, blackens the nitrate of silver beneath. The portion of nitrate of silver not blackened being removed by chemical process, the print exhibits a fine reduced drawing of the tracing. The photographer puts in the filling between the portions of the contours given on the positive, and it is then ready for the engraver.

In the economy both of time and money, the photograph promises to confer advantages similar to those derived from the electrotype. A numerical comparison with the time and cost of reducing by hand cannot yet be fully made, because it would require that several charts should be reduced by both methods. In one instance, however, where the comparison was made, the time was as days to weeks; and the expense was in like proportion.

The President of the British Association, Richard Owen, in the last published *address*, gives an account of the "advances achieved in this most subtle application and combination of discoveries in photicity, electricity, chemistry, and magnetism"; yet he makes no mention of its being used in the way just described. As far as we know, this application of heliography is original with the Coast Survey.

A special appropriation has been made by Congress for the publication of the records and results of the Coast Survey; and the work of the year 1849 has been selected to form the contents of the first volume of Geodesy, as embracing details of every class, and therefore suited to give a full view of all the operations.

It will contain detailed accounts of the measurement of a principal base line, and of some preliminary bases; of observations of angles for primary, secondary, and tertiary triangulations; of observations of latitude with the zenith sector and with the zenith telescope; and of observations of azimuth and of time. The description of instruments, and of methods of

observation and reduction, will form a necessary and valuable portion of the first volume. Another volume has been prepared, giving an account of the Coast Survey *Chronometric Expeditions for ascertaining the Longitude between Cambridge and Liverpool*, by Mr. George P. Bond, Director of the Cambridge Observatory. A volume containing the *Explorations of the Gulf Stream* has been prepared by the Superintendent, with the assistance of Professor A. G. Pendleton of the Navy. A volume containing the results for telegraphic longitude since 1852 is under the charge of Dr. B. A. Gould. There is also ready for publication a volume of *Sailing Directions* for the Coast of the United States, enbodying all the hydrographic information brought out in the progress of the Coast Survey, in reference to harbors, dangers, ports of refuge, and sailing marks and lines; in which last are included light-houses and beacons, currents and tides, and the variation of the compass.

We early took a deep interest in the prosperity of the Coast Survey, and having prophesied its usefulness, and vindicated its character when assailed, we have allowed ourselves to enjoy its success. If we shall appear to have reviewed it with too much partiality, it will be remembered that we have furnished a warrant for our favor by citing the opinions of those "whose judgments, in such matters, cry in the top of ours."

We have reserved for the last and most decisive proof of the justice of our criticism, the emphatic tribute paid to the Survey by the Royal Geographical Society of London, in adjudging to Dr. Bache the Victoria Gold Medal for the year 1858, in consideration of "his successful labors in carrying out the great Coast Survey of the United States of America."

"It would be impossible," said the President, in his address on the presentation, "to do justice to an extensive work of this sort, on an occasion like the present; but as the previous Reports of the celebrated Coast Survey, from 1844 to 1855 inclusive, are in our library, those of our associates, and of the public generally, who wish to form an estimate of their value, can do so at their leisure, and they will see how vastly our medallist has pushed on this great work. They will assuredly then rise from the examination with the thorough conviction that, whether we regard the science, skill, and zeal of the operators,

the perfection of their instruments, the able manner in which the Superintendent has enlisted all modern improvements into his service, the care taken to have the observations properly registered, his modest and unpretending demeanor, or the noble liberality of the government, tempered with prudent economy, all unprejudiced persons must agree that the Trigonometrical Survey of the United States of America stands without a superior."

ART. VIII. — *The Life of John Collins Warren, M. D. Compiled chiefly from his Autobiography and Journals.* By EDWARD WARREN, M. D. Boston: Ticknor and Fields. 1860. 2 vols. 8vo. pp. 420, 382.

As we have been recently reminded by Dr. Warren's successor, "the Professor at the Breakfast-Table," who can write about both as an expert, talent is of immeasurably higher value and larger availableness than genius. Pegasus, prancing in mid-air, is a spectacle to be gazed at and admired; but for the actual uses of this earthly life feet are worth more than wings, and the power of apprehending the things that are gives a working position and force, which may be supplemented, but cannot be compensated for, by the richest endowments of a creative fancy or a discursive imagination. In the subject of the memoir before us we discern talent of a rare and high order, without genius, or the show or pretence of it; and we are inclined to think that Dr. Warren's deficiencies contributed equally with his eminent gifts to constitute his merit and his fame. Among his many titles to reputation we suppose the foremost to have been that of a pre-eminently skilful and successful surgeon. The foundation for this transcending ability was, of course, the most thorough and accurate scientific knowledge of the anatomy of the human frame, not in theory alone, but in all the details of normal, abnormal, and morbid fact. In this department of knowledge there was equal need of the power of close inductive reasoning and of an inaptitude for rapid and hypothetical generalization. It was essential that theory should never exceed the